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M.R.P.978
S.C.II/209
30th April, 1956

AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE

Long-period averages for the upper air

by
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Summary

Average monthly pressures of the tropopause at Larkhill and Lerwick for 1942-1953 show an erratic variation from month to month, anomalous values occurring in months when the average sea-level pressures differ from the averages for the period 1900-1939. The average tropopause pressures are adjusted, by a simple regression method, to be in keeping with the average sea-level pressures for 1900-1939 and the upper air temperatures are also adjusted correspondingly. The resulting figures have a more regular variation through the year than the averages for 1942-1953.

1. Introduction

This study stems from an attempt to discover the seasonal variation of the tropopause over the British Isles. For this purpose the average pressure of the tropopause was computed for each month of the year for Larkhill and Lerwick for the 12-year period 1942-1953 inclusive. These are shown in Figure 1, together with the greatest and least monthly means observed in the period. It is seen from this Figure that the variation from month to month is irregular, especially in spring, and this suggested that the period of observations was not sufficiently long to yield reliable averages. The annual variation of the average monthly tropopause pressure in Canada [1,2] appears to be more regular though Moore's figures for Hanover [1] for the period 1948-1952 also show irregularities in the spring.

There is a rough relation between the height (or pressure) of the tropopause and the general character of the weather. The pressure of the tropopause is high in unsettled weather with low surface pressure and low temperatures in the troposphere and vice versa in anti-cyclonic weather [3].

The average monthly sea-level pressures for the points 60°N., 0°W., 50°N., 0°W. (as representing Lerwick and Larkhill respectively) for the period 1942-1953 were therefore compared with similar values for the period 1900-1939[4]. To do this daily values for these two points were extracted from the Daily Weather Report for the years 1942-1948*. For the remaining years 1949-1953 the values were taken from Die Grosswetterlagen Mitteleuropas[5]. The comparison is shown in Table I and it is seen that the average pressures for some months for the 12-year period differ considerably from those for the longer period and further that the months which show abnormally high pressure at the tropopause at Lerwick (Figure 1) also show a low surface pressure compared with the long-term values, and vice versa; this feature is not so well marked for Larkhill. It seems clear therefore that some or perhaps all of the irregularities in the average curves in Figure 1 are not representative of true long-term mean effects but arise because the period of observation is comparatively short.

/Adjustments

* Daily values were also extracted for other points at 60°N., and 50°N. at 10-degree intervals from 10°E. to 80°W. inclusive, for the same period.

Adjustments are therefore here suggested to the average monthly pressures of the tropopause at Larkhill and Lerwick so that these pressures are more in keeping with the corresponding average surface pressures for the period 1900-1939. Adjustments are also suggested to the average monthly temperatures at the tropopause and at standard levels, so that they are in keeping with these amended tropopause pressures.

2. Adjusted monthly averages of tropopause pressure

Dines [3] has shown that the height of the tropopause and surface pressure are related, correlation coefficient 0.68. This result was obtained by analysing ballon-sonde data from many stations in Europe for all seasons. The relation between monthly mean values of sea-level pressure and tropopause pressure at Larkhill and Lerwick is slightly closer. The Table II gives values of the correlation coefficients between these two variables for the mid-season months evaluated from the data for 1942-1953. The mean sea-level pressures at 50°N., 0°W., and 60°N., 0°W., were used for the mean pressures at Larkhill (51°N., 2°W.), and Lerwick (60°N., 1°W.) respectively. Each coefficient in Table II was evaluated from only twelve pairs of values and there does not appear to be any significant seasonal variation in the coefficients since the extremes at the two stations occur in different months. Accordingly the mean values of the coefficients were used in the following computations.

The average tropopause pressures were adjusted to correspond to the average sea-level pressures for the period 1900-1939 by simple regression equations using the data for 1942-1953 to evaluate the standard deviations and taking the mean values of the correlation coefficients (Table II) as described above. It was found that the standard deviation of mean tropopause pressure, as computed, varied erratically from month to month, a result which was to be expected as the number of observations from which each standard deviation was computed was small (12). These standard deviations were therefore smoothed graphically, conforming to a regular variation from a maximum in the late winter or early spring to a minimum in mid-summer, as indicated by the crude values. The amount of smoothing is shown in Figure 2. The standard deviations of monthly sea-level pressures did not vary in so erratic a manner as those for tropopause pressure and the crude values were used.

The adjusted average monthly pressures and the averages for 1942-1953 are given in Tables III and IV and are also shown in Figures 3 and 4. The other figures in these tables will now be described.

3. Adjusted monthly averages of temperature

The pressure of the tropopause and the temperatures in the troposphere and lower stratosphere are related [3,6]. The monthly means of the same quantities are also related and the mean temperature at the tropopause and the mean pressure of the tropopause are also associated. Table V shows average values of the correlation coefficients for Larkhill and Lerwick evaluated from the data for 1942-1953. As with the association between mean surface pressures and mean tropopause pressures there did not appear to be a significant seasonal variation in the coefficients and average values were used.

By means of simple regression equations the average temperatures at the levels 100, 200, 300, 500 mb. and the tropopause were adjusted to be in keeping with the adjusted tropopause pressures described in Section 2. Adjustments for the level 150 mb. were also made by direct interpolation. Since mean lapse rates in the troposphere are remarkably constant the same adjustments were made to the temperatures for 700 mb. as for 500 mb. The results are given in Tables III and IV, together with the averages for the period 1942-1953; some of the results are also shown in Figures 3 and 4. The adjusted values are given to the nearest degree Fahrenheit. The averages for the period 1942-1953 are given to the nearest 0.1°F. Radiation and lag corrections were not applied to the observations from which both these sets of averages were computed and the average temperatures at 100 mb. are therefore too high by amounts varying between about 2° and 3°F. depending on the season [7]. Errors at lower levels are smaller.

/It

It may be argued that the "corrected" long period average temperatures in Tables III and IV should have been computed directly from the relation between mean temperature and mean sea-level pressure. It was felt however that the method of computation described above produces a more consistent set of temperatures. The main connection between surface pressure and the tropopause is the association of low surface pressure with subsidence at tropopause level and vice versa. Having found the "correction" for the tropopause it seemed best to apply a similar type of correction to the temperatures at the other levels. Test computations of "corrections" to the temperature at 100 mb. directly from the sea-level mean pressures gave for Larkhill larger differences than shown by A-B in Table III (about double) so that the resulting average temperatures after "correction" appear irregular. Similar computations for Lerwick were impossible for winter and some spring months as the correlation coefficients between monthly mean temperatures at 100 mb. and monthly mean sea-level pressures were then very small.

4. Conclusions

The differences A-B in Tables III and IV are not large. Figures 3 and 4 show however that the estimated average values for the period 1900-1939 vary from month to month in a more regular manner than the averages for the period 1942-1953; this is more noticeable at Lerwick than at Larkhill. The method of estimating the averages for the long period is perhaps open to criticism, as any such estimation must be; however the self-consistency of the results gives some confidence in their reality.

If these results are accepted they demonstrate that upper air data for a few years are inadequate to provide a representative average. This is well known for meteorological data for the earth's surface. The results also show that in climatological studies of average values of upper air parameters it is advisable to analyse all the data for the same definite period of years; data for one short period of years may not be comparable with data for a different period.

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Table I

Mean sea-level pressures: (mb.-1000)

Period	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					50°N. 0°W.							
1942-53	16	18	18	16	16	17	17	15	16	17	15	16
1900-39	17	16	14	13	16	17	16	16	18	14	14	14
					60°N. 0°W.							
1942-53	7	9	14	8	16	12	12	10	9	11	8	6
1900-39	7	8	9	11	13	14	12	11	12	9	8	7

Table II

Correlation coefficients between monthly mean values of sea-level pressure and tropopause pressure. (From data for 1942-53)

	January	April	July	October	Mean
Larkhill	-0.91	-0.88	-0.63	-0.71	-0.78
Lerwick	-0.75	-0.59	-0.80	-0.88	-0.75

Table V

Average correlation coefficients between mean monthly values of pressure at the tropopause and temperature at

	100 mb.	200 mb.	tropopause	300 mb.	500 mb.
Larkhill	0.60	0.80	0.70	-0.70	-0.80
Lerwick	0.75	0.80	0.75	-0.60	-0.75

(computed from data for 1942-53)

Table III

Monthly average temperatures in the upper air and average tropopause pressures: observed 1942-53 (A) and estimated 1900-39(B). Larkhill

		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						°F.							
100 mb.	A	-71.4	-71.4	-69.0	-65.8	-60.7	-59.8	-59.5	-59.4	-66.1	-71.8	-75.4	-73.6
	B	-72	-71	-67	-64	-61	-60	-59	-60	-67	-71	-75	-73
150 mb.	A	-69.9	-69.7	-68.7	-63.8	-61.0	-60.3	-59.6	-60.0	-66.6	-71.0	-72.8	-70.9
	B	-70	-69	-67	-62	-61	-60	-59	-61	-68	-69	-72	-70
200 mb.	A	-72.3	-72.5	-73.9	-67.7	-64.7	-62.8	-60.6	-59.8	-64.2	-68.3	-70.9	-72.8
	B	-73	-71	-72	-66	-65	-63	-60	-61	-65	-66	-70	-72
Tropopause Pressure (mb.)	A	237	239	227	240	241	229	224	227	221	222	231	236
	B	235	243	236	249	241	229	228	224	215	231	234	240
Tropopause Temperature	A	-75.8	-76.1	-76.9	-72.3	-69.1	-67.1	-64.6	-64.0	-68.2	-71.2	-73.7	-75.6
	B	-76	-75	-75	-71	-69	-67	-64	-65	-69	-70	-73	-75
300 mb.	A	-56.4	-57.6	-55.8	-52.2	-50.1	-44.3	-40.5	-41.3	-42.4	-46.8	-51.5	-55.7
	B	-56	-58	-57	-53	-50	-44	-41	-41	-42	-47	-52	-56
500 mb.	A	-12.5	-12.8	- 8.6	- 7.3	- 4.0	2.3	6.5	5.9	4.2	- 0.3	- 6.2	-10.3
	B	-12	-13	-10	- 9	- 4	2	6	6	5	- 1	- 7	-11
700 mb.	A	16.5	16.4	20.3	21.7	25.7	30.5	34.0	33.0	31.7	28.3	22.0	18.8
	B	17	16	19	20	26	31	33	33	33	27	22	18

A Averages for the period 1942-53.

B Estimated averages for the period 1900-39.

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Table IV

Monthly average temperatures in the upper air and average tropopause pressures: observed 1942-53 (A) and estimated 1900-39 (B).
Lerwick

		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						°F.							
100 mb.	A	-73.8	-72.4	-69.2	-59.7	-56.2	-51.2	-50.4	-51.6	-58.3	-67.0	-72.7	-73.4
	B	-74	-72	-66	-61	-55	-52	-50	-52	-59	-66	-73	-73
150 mb.	A	-70.4	-69.6	-67.5	-57.9	-56.3	-51.0	-50.7	-52.9	-58.2	-66.2	-68.9	-70.0
	B	-70	-69	-64	-60	-54	-52	-51	-54	-60	-65	-69	-70
200 mb.	A	-72.0	-71.6	-70.7	-60.6	-61.1	-53.0	-52.8	-55.6	-58.5	-65.9	-67.8	-70.8
	B	-72	-71	-67	-63	-59	-54	-53	-56	-60	-65	-68	-70
Tropopause Pressure (mb.)	A	255	254	248	271	253	260	249	242	246	239	253	255
	B	255	256	262	261	263	254	249	239	238	244	253	253
Tropopause Temperature	A	-75.7	-76.4	-75.5	-66.9	-67.5	-61.0	-62.0	-63.9	-64.1	-69.7	-71.0	-74.5
	B	-76	-76	-73	-69	-66	-60	-62	-64	-66	-69	-71	-74
300 mb.	A	-61.5	-61.9	-59.6	-55.1	-51.9	-47.2	-45.5	-45.8	-46.9	-50.6	-56.3	-59.2
	B	-61	-62	-61	-54	-53	-46	-45	-46	-46	-51	-56	-59
500 mb.	A	-19.2	-19.8	-16.3	-14.8	- 7.3	- 3.5	- 0.7	- 0.9	- 3.1	- 5.7	-13.2	-16.5
	B	-19	-20	-19	-13	- 9	- 3	- 1	0	- 2	- 6	-13	-17
700 mb.	A	10.1	9.6	12.4	14.0	20.8	24.4	28.4	28.7	24.6	22.3	15.1	13.2
	B	10	9	10	16	19	25	28	29	26	22	15	13

A Averages for the period 1942-53.

B Estimated averages for the period 1900-39.

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Fig.1

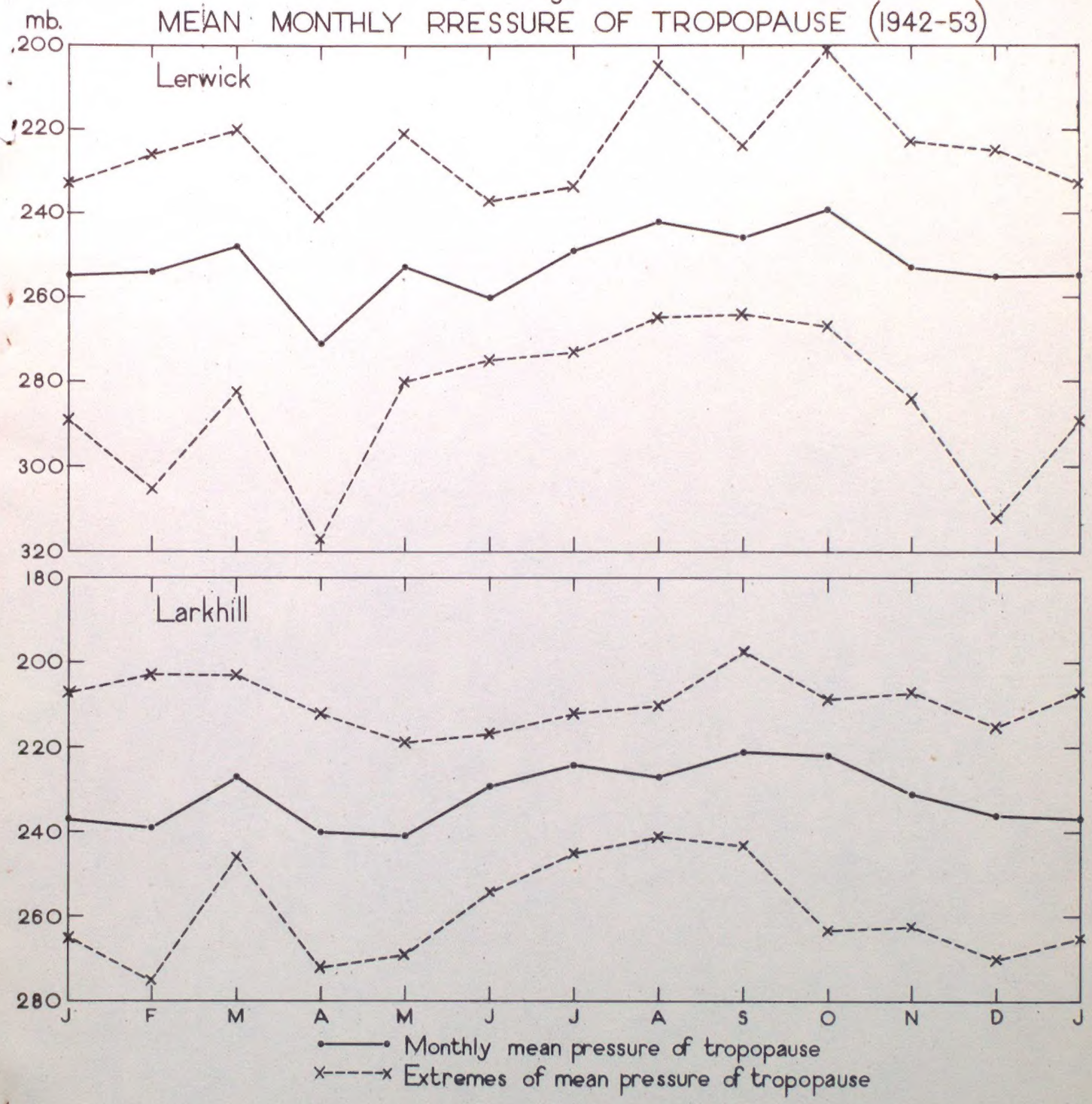

MEAN MONTHLY PRESSURE OF TROPOPAUSE (1942-53)
mb.
200
220
240
260
280
300
320
Lerwick
180
200
220
240
260
280
Larkhill
J
F
M
A
M
J
J
A
S
O
N
D
J
Monthly mean pressure of tropopause
Extremes of mean pressure of tropopause

Fig. 2

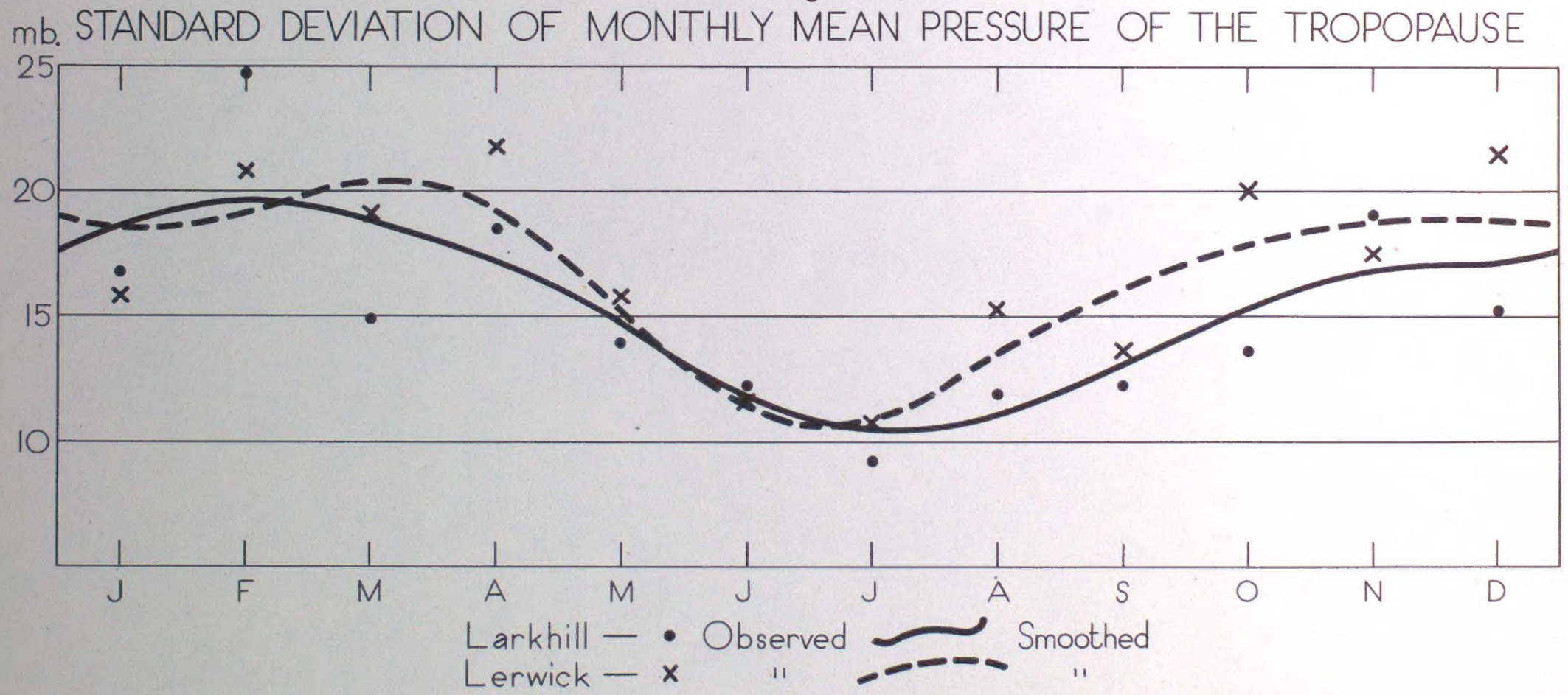

mb. STANDARD DEVIATION OF MONTHLY MEAN PRESSURE OF THE TROPOPAUSE
25
20
15
10
J
F
M
A
M
J
J
A
S
O
N
D
Larkhill — • Observed
Smoothed
Lerwick — × "
"

Fig. 3

MEAN TEMPERATURE AND MEAN PRESSURE OF THE TROPOPAUSE, LARKHILL

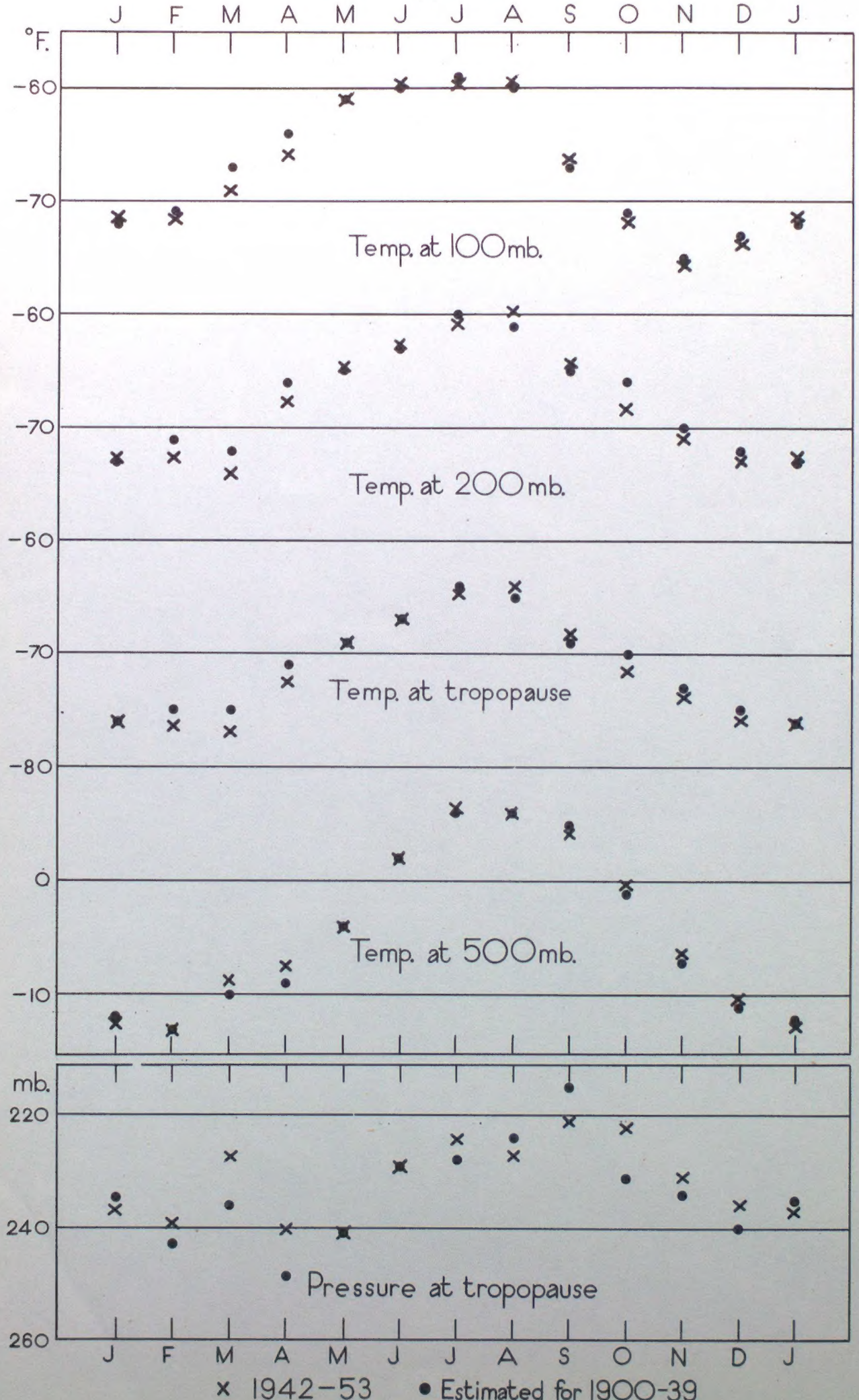
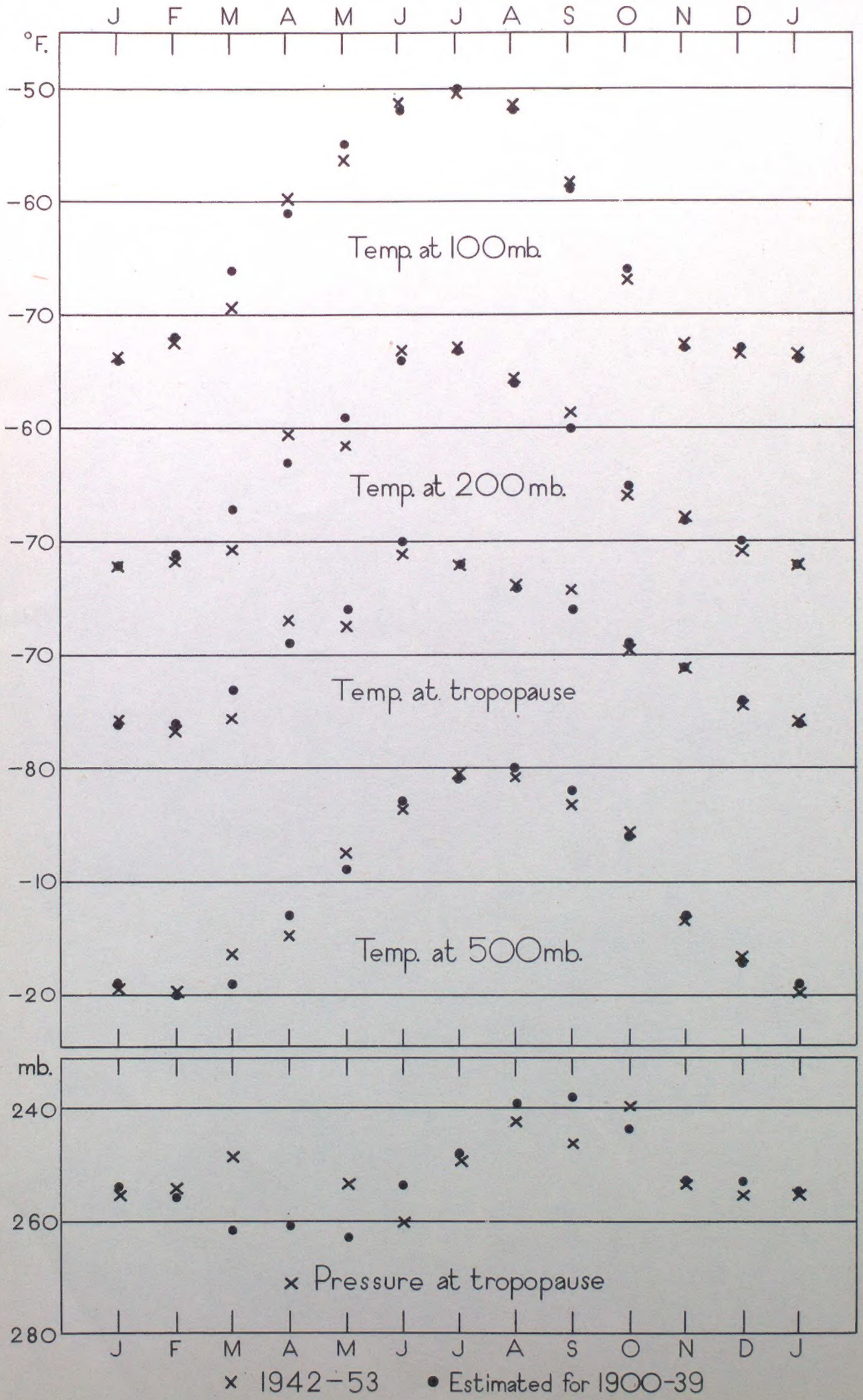


Fig. 4 M.R.P. 978

MEAN TEMPERATURE AND MEAN PRESSURE OF THE TROPOPAUSE, LERWICK